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(71) Applicant (for all designated States except US): SANDVIK AB (publ) [SE/SE]; S-811 81 Sandviken (SE).			
(72) Inventors; and (75) Inventors/Applicants (for US only): SALOMONSON, Jonas [SE/SE]; Solfagravägen 132, S-141 45 Huddinge (SE). ODÉN, Agneta [SE/SE]; Bergstigen 26, S-182 74 Stock- sund (SE).			
(74) Agent: TÅQUIST, Lennart; Sandvik AB, Patent Dept., S-811 81 Sandviken (SE).			
(54) Title: METHOD FOR MAKING CERAMIC ARTIFICIAL DENTAL BRIDGES			
(57) Abstract			
<p>The present invention relates to a method for making artificial tooth bridges consisting of a ceramic densely sintered high strength individual core (B) veneered with porcelain (A) using powder metallurgical methods. According to the method the individual densely sintered bridge parts are joined together to a bridge core with glass, which in molten condition wets the ceramic core material. The glass therefore finds its way into the gap between the bridge parts and reacts with the ceramics so that it during cooling forms a strong joint between the individual densely sintered ceramic bridge parts.</p>			

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Method for making ceramic artificial dental bridges

The present invention relates to a method for making artificial dental bridges accurate to shape in high strength ceramic material with powder metallurgical methods as well as by joining of two or more ceramic parts to each other.

US 5,342,201 discloses a method of manufacturing artificial tooth restorations to natural teeth or implants consisting of a ceramic densely sintered high strength core veneered with dental porcelain by powder metallurgical methods.

The object of the present invention is to achieve a rational manufacturing technique for dental bridges in densely sintered high strength ceramic material using modern powder metallurgical technique, registering technique and joining technique. Dental bridges in e.g. densely sintered high strength alumina offer a combination of mechanical strength, biocompatibility and esthetics which is generally not possible with established dental materials and methods intended for dental bridges.

The present invention relates to a method of manufacturing artificial dental bridges in densely sintered ceramic material by joining two or more densely sintered ceramic parts with the aid of glass or sintering technique. The individual parts, whose inner surface which should fit against one or more prepared tooth surfaces or artificial abutments, are made by forming a ceramic powder mixture against a surface of a body whereby said surface is made using a three-dimensional optical or mechanical reading method in which the surfaces of the prepared teeth or artificial abutments and their mutual relationship are registered, either directly in the mouth or on a model in e.g. plaster whereafter the registered surfaces are reproduced in an enlarged format

e.g. with the aid of a computer controlled milling machine whereby the magnification is calculated considering the shrinkage of the ceramic material during sintering to full density with addition of desired gap required for cement according to US 5,342,201 and US 5,080,589.

Fig. 1 shows a cross section of a natural tooth with an artificial tooth crown. In this figure, A= dental porcelain, B= core, Y= outer surface of the core, I= inner surface of the core, C= cement, P= prepared surface of the tooth, S= preparation border, E= enamel, D= dentin and F= pulp.

Fig. 2 shows a cross-section of a bridge containing three joined parts. The bridge is cemented on two supporting teeth. These supporting teeth may have a vital abutment (U1) or an artificial abutment (U2) manufactured in some dental alloy, ceramic material or some reinforced polymer. The bridge contains two artificial tooth crowns according to Fig. 1 and with a central pontic (V), as a substitute for a lost tooth. These units are joined at high temperature through addition of a glass, which in melted condition wets the core material and spreads into the gap between the individual bridge parts. During cooling the glass will solidify and a high strength joint (Q) joining the bridge units is obtained. The bridge consists of a core (B) with veneered dental porcelain (A). A bridge can be cemented on more than two supporting prepared teeth and thus contain more than one pontic. The supporting teeth can also be prepared for inlays or veneers. Veneers can be made for both buccal and lingual surfaces. The supporting teeth can even be implants or artificial abutments.

As is shown in Fig. 2 artificial dental bridges are made as a core in densely sintered ceramic (B) with veneered dental porcelain (A). The core consists of two or more parts joined together with glass which is heat-

treated and joins by melting/solidification. The bridge is fixed against the abutments (U1) and (U2) by e.g. cementing.

The ceramic powder can be made of several methods 5 well known to the skilled artisan. Traditional powder metallurgical technique can be used, where the different components are mixed and milled in dry or wet condition with water or a solvent e.g. alcohol, as a milling liquid. To the ceramic slurry, lubricants or other organic 10 binders, are added when needed at a suitable time in the process.

The ceramic base material of the core comprises 15 preferably one or more biocompatible oxides (including phosphates, silicates and sulphates), with additives of carbides, silicides, nitrides or borides with or without binder metal in addition to conventional sintering aids. The base material can also comprise other high performance ceramics which are biocompatible such as nitrides, oxynitrides, sulphides, oxysulphides or similar phases 20 as well as of ceramic materials containing halogens. Examples of biocompatible oxides, which can form base matrix for the ceramic body, are oxides such as  $Al_2O_3$ ,  $TiO_2$ ,  $MgO$ ,  $ZrO_2$  and  $ZrO_2$  with additives of smaller amounts of up to 10 mol%  $Y_2O_3$  or  $MgO$  (partly or completely stabilized  $ZrO_2$ ). In a preferred embodiment the 25 ceramic material comprises >50%, preferably >85%,  $Al_2O_3$  with additives of conventional sintering aids. It is important that the ceramic material is sintered to closed porosity, which for an oxide material means at least 98% 30 of theoretical density, but in order to ensure good mechanical strength, the material should preferably have a density over 99% with densities over 99.5% giving the best strength.

According to the present invention the bridge units 35 such as tooth copings and one or more pontics as substitute for lost teeth are made with the technique accord-

ing to US 5,342,201 and US 5,080,589. As an alternative to the conventional technique with pressing and sintering the body can be produced by EPD (Electrophoretic Deposition) in order to subsequently be sintered in a conventional manner. The bridge units should subsequently be joined with a high demand on strength and fit on the joined bridge. In order to obtain an acceptable fit the bridge units should remain in their mutual positions during the whole joining process. By performing the joining process with the bridge units placed on a refractory die e.g. a refractory replica of the base model of the situation in the mouth, the position of the bridge units can be locked during the joining process and it is possible to obtain optimal fit. A glass can be used as joining material which has to have the characteristic properties of wetting the densely sintered ceramic material i.e. the glass should have a lower surface energy at the temperature used during the joining process than the ceramic material in the bridge units. This melted glass will easily spread out over the surfaces of the bridge units in order to lower their surface energy. The melted glass must have a low viscosity in order to be able to spread into the gap between the bridge units. Furthermore, the glass should have the characteristic property that it reacts, not too little and not too much, with the ceramic material in the bridge units in order to get an optimal bond between glass and ceramic material in the joint. In order to obtain this the glass should contain the same metal oxides as the material in the bridge units. This amount should be less than saturation level of the mentioned metal oxides in the glass at the joining temperature. The thermal expansion coefficient must be lower than or equal to the ceramic material in the bridge units in order to avoid development of fractures during cooling. The melting temperature of the glass must be higher than the

melting temperature of the veneering porcelain in order to avoid distortion of the bridge during the subsequent firing of porcelain. The joint should be designed so that a certain mechanical locking is obtained in the direction of the main force in order to obtain an optimal strength. If the joining process of the bridge units is made with a correct refractory replica of the base model, a correctly shaped joint and with a glass with properties according to above the joined bridge becomes very strong in compression at the same time as the fit can be optimal. An example of important main constituents in a glass composition that works well when joining highly pure alumina is:  $\text{SiO}_2$  32 mol%,  $\text{B}_2\text{O}_3$  24 mol%,  $\text{Al}_2\text{O}_3$  18 mol% as well as  $\text{La}_2\text{O}_3$  12 mol%. A bridge joined with glass, can subsequently be veneered with one or more layers of dental porcelain in order to obtain a good esthetics. The advantage with manufacturing bridges with the technique according to the present invention is that e.g. densely sintered high strength alumina can be joined together which results in a dental bridge with high strength, optimal fit and an esthetics which can not be obtained with conventional dental bridges of e.g. metal ceramics.

CLAIMS

1. Method of making artificial dental bridges consisting of a ceramic densely sintered high strength individual core (B) veneered with porcelain (A) by powder metallurgical methods characterised in that the individual densely sintered bridge parts are joined to a bridge core with glass, which in melted condition wets the ceramic core material and therefore spreads into in the gap between the bridge parts and reacts with the ceramic such that the glass during cooling forms a strong joint between the individual densely sintered ceramic bridge parts.
2. Method according to claim 1 characterised in that the core material consists of high strength ceramic material with a relative density >98%.
3. Method according to claim 1 characterised in that the ceramic core material consists of one or more of the oxides  $Al_2O_3$ ,  $TiO_2$ ,  $MgO$ ,  $ZrO_2$  or  $ZrO_2$  with up to 10 mol%  $Y_2O_3$ ,  $MgO$  or  $CaO$ .
4. Method according to claim 1 characterised in that the glass being used for joining has a surface energy at the joining temperature lower than the surface energy for the densely sintered core material.
5. Method according to claim 1 characterised in that the glass contains the same metal oxides as the core material in an amount that falls below the degree of saturation of the mentioned metal oxides in the glass at the joining temperature.
6. Method according to claim 1 characterised in that the glass has a coefficient of thermal expansion which is lower than or the same as the coefficient of thermal expansion of the densely sintered core material.

7. Method according to claim 1

characterised in that the glass contains the following main constituents:  $\text{SiO}_2$  32 mol%,  $\text{B}_2\text{O}_3$  24 mol%,  $\text{Al}_2\text{O}_3$  18 mol% as well as  $\text{La}_2\text{O}_3$  12 mol%.

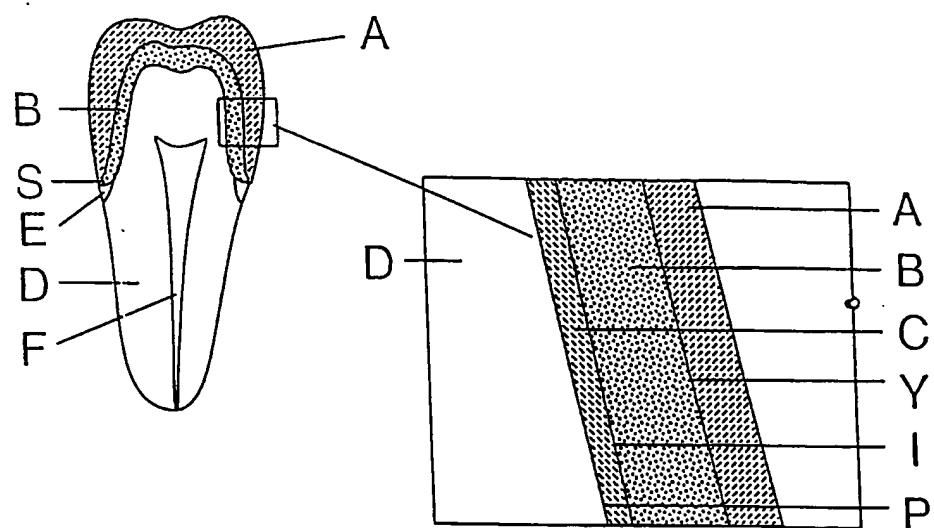


Fig. 1

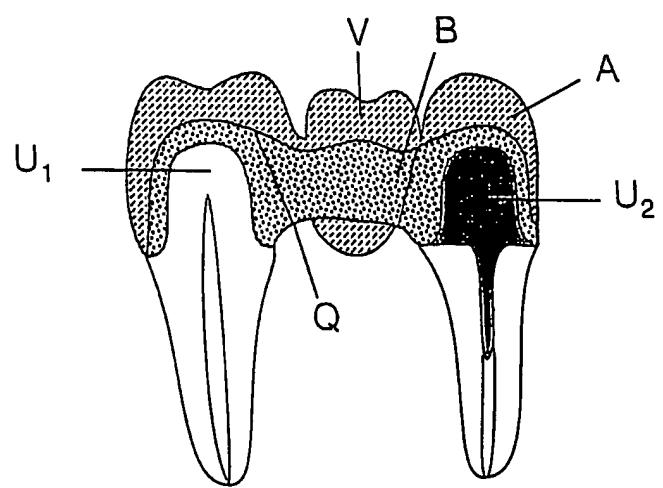


Fig. 2

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/01620

## A. CLASSIFICATION OF SUBJECT MATTER

## IPC6: A61C 13/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

## IPC6: A61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0375647 A2 (SANDVIK AKTIEBOLAG), 27 June 1990 (27.06.90) --	1-7
A	EP 0580565 A2 (SANDVIK AKTIEBOLAG), 26 January 1994 (26.01.94) -- -----	1-7

 Further documents are listed in the continuation of Box C. See patent family annex.

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## INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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